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THEORY AND SIMULATION OF LASER PLASMA INSTABILITIES IN IGNITION SCALE PLASMAS*

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National Ignition Facility (NIF) hohlraums are calculated to have several millimeters of hot, low Z, fairly uniform plasma through which the laser propagates before it deposits its energy in high-Z, high-density wall plasma. The radiation produced by the wall plasma drives the capsule. Successful implosions demand that the laser propagate with acceptable energy losses to stimulated Brillouin (SBS) or Raman (SRS) scattering. In addition, Brillouin and Raman sidescattering and filamentation must be controlled so that the radiation flux on the capsule remains within design tolerance. Because of the large gain exponents calculated in NIF hohlraums from these three processes, both nonlinear processes and the effects of laser beam smoothing in 3D must be understood to predict the results.

Theoretical analysis is bolstered by the use of fluid and particle-in-cell (PIC) simulations. Recently, we have completed the development of a 2D fluid-electron, particle-ion code coupled to light with a enveloped-in-time wave equation that allows the study of the saturation of SBS on the long time scale of the ion motion, bypassing the fast time scale of the electron dynamics. Two dimensional effects are found to be extremely important. We find that, after a transient period in which SBS evolves similarly to its evolution in 1D calculations, the ion waves driven by SBS drop to much lower levels and remain there. The time at which this transition occurs is associated with the appearance of a rich spectrum of ion waves propagating at large angles to the primary SBS ion wave. Theoretical analysis shows that both modulational and decay instabilities are responsible. The growth rates have been found in the novel regimes of high-temperature, low-density, and multispecies plasmas where kinetic effects and charge separation are important.

Filamentation and SBS have been calculated in 3D with the use of the F3D code which solves the nonlinear hydrodynamic equations coupled to a set of paraxial equations to describe the incident and SBS reflected light. The 3D fully-nonlinear ion dynamics is a recent addition which allows us to study strongly self-focussed light that evacuates a plasma channel. Two problems of particular interest are the control of filamentation with time-dependent beam smoothing schemes such as SSD (smoothing by spectral dispersion) and the deflection of the laser beam in plasmas with flows transverse to the laser propagation direction. We find that a few angstroms of bandwidth, ~.02-.05% of the laser frequency, is sufficient to prevent filamentation of the hotspots in conditions of interest to NIF. Flow across the laser beam causes deflection because the density hole induced by the laser moves such that the density gradient is nonzero at the peak intensity location. The laser light is then refracted in the flow direction. With supersonic transverse flow, filamentation is stable but then forward SBS is unstable which also deflects the beam in the flow direction. Surprisingly perhaps, SSD can still control filamentation with flow without additional bandwidth. On a longer time scale, inhomogeneous axial flow also influences filamentation and beam deflection because the density structures produced at higher density are convected downstream.

SRS in structured laser beams in which filamentation is occurring may be the most important instability to understand because it has been observed at high levels in

experiments and there is evidence that it influences strongly the level of SBS. Both PIC and multidimensional fluid simulations of this interaction are in progress.

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